(5) Other responses are those due to self-product modulation of the signal itself, causing a beat which falls into the first i-f passband. These are relatively insignificant since the frequency range of interference is quite small. The even-order self-products can be suppressed by balanced mixers to any degree desired.

(6) Figure 3 shows the relationship between spurious frequencies of various orders versus the frequency to which the receiver is nominally tuned. This again is for a first i-f frequency 400-mc. By resolving the 50-to-300 mc range into the proposed sub-bands of 50 to 90 mc, 90 to 160 mc, and 160 to 300 mc, respectively, the more significant spurious responses (second order) can be suppressed. The second-order self-product response of 200 mc would appear in the i-f stage; however, this could be effectively eliminated by a balanced-mixer process. Only the 160-to-300 mc sub-band would be subjected to third-order effects, which occur in the last 60-mc frequency range.

(7) Other factors influence the desirability of providing sub-bands essentially in the way proposed above. Since the first local oscillators used in the sub-band converters are crystal controlled, there are practical limitations on crystal frequencies. Over-tone crystals generally are not feasible above approximately 200 mc. With the proposed sub-band converter configuration shown in figure 4, the desired local-oscillator frequencies would require frequency multiplication. By selecting crystal frequencies within the 100-to-200 mc range, it would be possible, by a total frequency multiplication of four, to obtain the desired local-oscillator frequency ranges. An important design consideration in the selection of such a frequency multiplication process is to avoid spurious local-oscillator frequencies, due principally to the third and fifth harmonics of the crystals. It is proposed to minimize this

effect in the multiplication process by the use of "push-push" doublers. With the sub-bands proposed, it is estimated that these measures, when used with practical-design bandpass filters between the frequency multiplier and the first mixer, would provide adequate suppression of spurious local-oscillator frequencies.

(8) The proposed design of the sub-band converter units is basically quite simple. A bandpass filter and a buffer r-f amplifier of small gain are used to couple the broadband r-f preamplifier and the first mixer associated with the particular converter. It is expected that the mixer would be balanced (especially at 200 mc, in the high-band converter). The crystal oscillators would be made up of over-tone crystals each with its own transistor oscillator. Frequency multipliers would likely be vacuum tubes since transistor performance at the present time is marginal in the frequency range desired. Frequency switching would be accomplished by actuating, in proper sequence, the individual oscillators with voltages derived from a counter-matrix. The count standing in the matrix at any time is indicative of the crystal selected and, hence, the most coarse frequency setting of the receiver. The counter is actuated by an advance pulse received from the sweep and lock-on logic sub-unit.

b. Fine-Tuning Receiving/Detection Unit

(1) As shown in figure 5, the fine-tuning receiving/detection unit is basically a complete narrow-band receiver having a center frequency of 400 mc and capable of tuning a 10-mc range. It is a dual-conversion receiver, with the first conversion process being accomplished in a conventional manner; signals in the 10-mc-wide input band centered at 400 mc are heterodyned into a 10-mc band centered at 17.5 mc. The second conversion process is similar to the one proposed for the sub-band converters. The choice of

local-oscillator range and final i-f center frequency is such that all second-order spurious-response problems are eliminated, and third-order effects exist only in a small part of the upper end of the tuning range. The second local-oscillator is intended to be self-controlled and is subjected to frequency change by means of changes in appropriate reactive elements through the use of a stepping counter and matrix. Stability requirements on this oscillator are relatively high. Long-term stability is not extremely important but drift rate is required to be low in order to be compatible with the phase-lock features to be provided in the system. It is expected that a drift rate not exceeding a few cycles per second can be readily obtained.

(2) The third i-f of the system will have a center frequency of 47.5 mc, and a bandwidth of 0.5 mc. It is proposed that all of the selectivity be in the first two stages of the i-f amplifier where a minimum of gain will be provided. Most of the required gain will be provided in stages having fairly wide bandwidths, where such effects as AGC will have no substantial influence on bandwidth. It is proposed that these i-f amplifier strips be completely transistorized. By providing selectivity where gain changes do not occur in the amplifier, the usual difficulties obtained with gain-controlled transistorized amplifiers will be substantially eliminated.

(3) As shown in figure 5, the detection and threshold circuitry proposed for handling regular AM, pulse, and FM signals closely resembles those now used in existing Band 1 receiving equipment. As indicated previously, these circuits will be completely transistorized.

(4) A block diagram of the coherent detection sub-unit is shown in figure 6. Basically, it is simply a means to provide for translation of a coherent r-f signal down to the original-modulating-frequency spectrum. The signal at the

third intermediate frequency of 47.5 mc is applied to two mixers. The heterodyning signal for these mixers is offset by 5 mc from the center frequency of the information-carrying signal. The two local-oscillator voltages are in phase quadrature. The resulting output signal from each mixer is applied to a balanced phase discriminator; the sum beat-frequency of these two signals is applied to a bandpass amplifier centered at 10 mc. An error signal is recovered by a synchronous detector operating at 10 mc; this feed-back signal is applied to the 47.5-mc local oscillator through a low-pass filter.

(5) The action of the phase-lock device is similar to that of conventional phase lock-on circuits with the exception of the frequency-offset procedure used. In normal phase-lock devices, there is no offset and it is necessary that the phase discriminator be fairly well balanced at zero frequency. Since, normally, the i-f noise will be over-riding the types of relatively narrow-band coherent signals under surveillance, balance problems at dc will be formidable. By using a frequency offset, the balance problems in the phase discriminator will be solely those of an a-c nature. Actually, if the phase discriminator were ideal; i.e., a true product device, no balance per se would be necessary.

(6) The 5-mc reference oscillator is advanced in approximately 10-kc steps when in a searching phase. Threshold circuits following the narrow-band 5-mc i-f amplifier and detector cause the sweep-logic circuitry to initiate a slow, vernier sweep applied to the reference oscillator, thus permitting phase lock-on when a signal appears within the 100-cycle band defined by the low-pass filter in the feed-back loop.

(7) The circuitry necessary to provide a coordinated sweeping and lock-on program for a receiving channel will

be contained in the sweep and lock-on logic sub-unit shown in figure 5. It will be made up entirely of basic logical units involving logic gates, storage elements (such as flip-flops), pulse generators for developing counting pulses, and possibly some relays.

(8) A typical sweep and lock-on program to be applied might be described as follows: Assuming a crystal-oscillator channel has been selected in a corresponding sub-band converter unit, the sweep and lock-on logic initiates a frequency-stepping search in the fine-tuning receiver by successively advancing the frequency of the 60-to-70 mc local oscillator in 500-kc steps. With the philosophy advanced in Section 2 regarding intercept and processing of signals, the minimum dwell-time during this stepping process would be 10 ms. If no signal intercept of any kind were manifest, the stepping procedure would continue into the next 500-kc interval. If an antenna switching function is included (for example, if selection of either a right-looking or a left-looking antenna is required), then the entire search procedure for the fine-tuning receiver would be effected twice before change in the oscillator frequency of the frequency-converter unit would be ordered.

(9) In the event that either the pulse or standard AM threshold is exceeded during a 10-ms dwell-time, outputs of the respective threshold circuits will initiate a timing action in the sweep and lock-on logic sub-unit. This timing action will eliminate any further frequency stepping until the "lock-on" operation is completed.

(10) At the start of a 10-ms dwell-time by the 60-to-70 mc local oscillator, the sweep and lock-on logic sub-unit also starts a sweep of the 5-mc reference oscillator in the coherent detection sub-unit. This is stepped in approximately 10-kc steps across the 500-kc band defined by the third i-f

amplifier. Actuation of the threshold circuit within the coherent detection sub-unit causes the stepping action of the 5-mc reference to cease. A slow-search sweep over approximately a 10-kc band is initiated and applied to the 47.5-mc local oscillator. This action serves to search within the 10-kc band at such a rate that the lock-on loop may acquire the signal.

(11) If the standard pulse or AM thresholds have been actuated, then, at the termination of the lock-on cycle, the receiver will be blanked for one frequency step and then completely restored to full-intercept capability. If, however, there is no threshold action in the standard pulse or AM channels within the 10-ms dwell-time, but threshold occurs in the coherent detection sub-unit, then the audio and video outputs from the coherent detection sub-unit are transferred by action of the sweep and lock-on logic sub-unit to the respective AM and video output busses. If there is no threshold action other than in the coherent detection sub-unit, the stepping action of the 60-to-70 mc oscillator will not be resumed until a complete frequency search has been made of the 500-kc segment and all distinct "lock-ons" serviced. This will be repeated if switched antennas are required. On break of lock, blanking is applied so that threshold action is disabled for at least a basic bandwidth separation of approximately 10 kc.